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(54) Title: METHOD AND DEVICE FOR MAGNETRON SPUTTERING

(57) Abstract

Method of magnetron sputtering, where a volume over the sputtered cathode surface is affected by a magnetic field and the field lines of the said magnetic field, which intersect the cathode surface twice, are spread on an area greater than 80 % of the total cathode surface area. The extinction pressure has a value greater than or equal to $1.5*10^{-2}$ Pa. Selected materials can be sputtered at the discharge power density of the cathode in the interval 2 to 250 W/cm^2 in a stable selfsputtering discharge, excited in the atmosphere of the sputtered atoms or in the mixture of the sputtered atoms with the working gas at pressures even lower than $1.5*10^{-2}$ Pa. Described are methods of discharge ignition and of adjustment of its characteristics by means of the magnetic field and other parameters. The method can be realized in a device for magnetron sputtering with a defined sputtered cathode surface consisting of an effective cathode area occupying at least 80 % of the total sputtered cathode surface, of a central cathode area and of a marginal cathode area. Various cathode shapes and magnetic field supplies are described.

electromagnet

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DESCRIPTION

Method and Device for Magnetron Sputtering

Technical Field

The invention concerns a method and a device
for magnetron sputtering of materials and it solves
the adjustment of discharge characteristics of the
5   magnetron discharge, especially the excitation of
a glow discharge at very low pressures, down to
$1.5*10^{-2}$ Pa for any cathode material, and even at
pressures lower than $1.5*10^{-2}$ Pa, down to the base
pressure of the vacuum device, for selected cathode
10 material in selfsputtering mode.

Prior Art

The cathodic sputtering in a d.c. glow dischar-
ge is a well-known process, utilized e.g. for deposi-
15 tion of thin films. The classical diode sputtering in
a glow discharge between a cathode and an anode is
not effective due to a low degree of gas ionization,
enabling operation only at high working gas pressu-
res, in the order of magnitude of 10 to 100 Pa. To
20 achieve lower working pressure, various ways are
used, the most usual of them being based on the mag-
netron principle, protected e.g. by the U.S. Pat. No.
3 878 085 (1975) and U.S. Pat. No. 4 166 018 (1979).
In a planar magnetron, over the cathode, a magnetic
25 field is generated in a form of a closed tunnel of
field lines between two concentrically arranged poles
and, as a result of the electron drift in crossed
electric and magnetic field, the path of electrons
gets considerably longer and their ionization ability
30 is increased. When a voltage, usually about 500 to

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1000 V, is led between the cathode and the vacuum
chamber, at a pressure at least equal to an ignition
pressure, usually between $5*10^{-1}$ Pa and 10 Pa,
a stable glow discharge is excited and then a working
5   pressure is set to a value greater than the extincti-
on pressure, at which the discharge extinguishes
spontaneously. The extinction pressures in magnetrons
are usually in the range $2*10^{-1}$ to 1 Pa. Only as an
exception, the magnetron glow discharge is stable at
10   a working pressure less than about 10^{-1} Pa, the lower
limit being about $5*10^{-2}$ Pa, according to J.L. Vossen
and W. Kern (eds.), Thin Film Processes, Academic
Press, New York, 1978. The reason for it is that
a particular minimum density of molecules above the
15   cathode is necessary for stable discharge excitation.

Besides the conventional balanced magnetron as
described above, also unbalanced magnetrons have been
developed, described e.g. in the papers B. Window and
N.Savvides: Journal of Vacuum Science and Technology
20   A 4, (1986) 196 and J. Musil, S. Kadlec a W.D. Münz:
Journal of Vacuum Science and Technology A 9,(1991),
1171. The difference between the balanced and un-
balanced magnetron consists in that in the case of
the balanced magnetron the magnetic field at the cat-
25   hode center is as strong as at the edge, whereas in
the case of the unbalanced magnetron the field is
either stronger in the center (unbalanced magnetron
- type 1) or at the edge (unbalanced magnetron
- type 2). In the unbalanced magnetron - type 2, the
30   orientation of the magnetic field at the axis is re-
versed at a particular distance from the cathode,
where the field of the outer pole predominates over
the field of the inner pole. In practice, the name
"unbalanced magnetron" is used for the unbalanced
35   magnetron-type 2, because it exhibits higher plasma

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density at the substrates as compared to both the
balanced magnetron and unbalanced magnetron-type 1.
All these magnetrons have rather similar magnetic
field at the cathode vicinity, in the shape of
5   a closed tunnel of field lines between two concentric
poles, and therefore it is possible to call their
magnetic field "a magnetic field of the magnetron
type". Even at the unbalanced magnetrons, lower ex-
tinction pressure than at the conventional ones is
10 not known. Also the values of the mean power density
of the magnetron discharge at the cathode surface are
normally in the order of magnitude of 1 to 20 W/cm^2
both in the conventional and the unbalanced magnet-
rons.

15   Extinction pressures values approximately
$2*10^{-2}$ Pa to $3*10^{-2}$ Pa have been achieved at magnet-
ron systems with special, exceptionally good plasma
confinement at the magnetron cathode, using combina-
tions of magnetic and electric fields. One of such
20 systems is a combination of two circular magnetrons
of the same size, placed against each other with op-
positely oriented magnets, see M. Matsuoka, Y. Hoshi,
and M. Naoe: Journal of Applied Physics, 60 (1986),
2096. Another method of achievement of low extinction
25 pressures in magnetron sputtering, protected by the
Czechoslovak patent application No. PV 4804-89, uti-
lizes a combination of a magnetic field of a conven-
tional or an unbalanced magnetron with a multipolar
magnetic field.

30   A mechanism of confinement of a d.c. magnetron
glow discharge, at pressures by orders of magnitude
less than 10^{-2} Pa, has been published in the paper
N. Hosokawa, T. Tsukada and H. Kitahara, Proc. of
8th International Vacuum Congress (Cannes, 1980),
35 vol. 1. This glow discharge was observed at a magnet-

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ron with a cylindrical cathode made of copper. The
authors have shown that when the magnetron discharge
is ignited at a common ignition pressure, in the or-
der of magnitude 10^{-1} Pa, and after the power density
5   at the cathode is increased over a particular minimum
value, about 100 W/cm^2, the density of sputtered cop-
per particles raises to such an extent that the dis-
charge is sustained even after a reduction of the
working pressure below 10^{-2} Pa. This discharge has
10   been given the name "sustained selfsputtering dis-
charge", because it is excited and sustained in
a cloud of the sputtered material itself, which is
being ionized in the discharge and it sputters back
the cathode surface. Such a selfsputtering discharge
15   then can be excited at very low pressures of the wor-
king gas, for example at the residual pressure of the
vacuum device. For its stability, three conditions
are essential:

1. High enough sputtering yield S;
20   2. High enough probability a of sputtered metal
ionization;
3. High enough probability b of the ionized metal
return back to the cathode.

      To sustain a stable selfsputtering discharge,
25   it is necessary to ensure that the following relation
holds:

$$a.b.S > 1$$

      The first condition is related to the choice of
the cathode material and of the working discharge
30   voltage. The second condition limits in practice the
selfsputtering to high enough current and power den-
sity at the cathode, because the probability a is
approximately directly proportional to the current
density at the cathode. The quality of plasma confi-
35   nement in the discharge is reflected in the combina-

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tion of the second and third conditions. The funda-
mental question of the prior art in the selfsputte-
ring discharge technology is finding the optimum way
of plasma confinement.

5   Besides the above-mentioned cylindrical magnet-
ron, a stable sustained selfsputtering discharge was
achieved also in a conventional planar magnetron with
a wide profile of the erosion zone, according to the
invention of M. Geisler, J. Kieser and R. Kukla, DE
10   3527626 A1, see the paper: R. Kukla, T. Krug,
R. Ludwig and K. Wilmers, Vacuum 41 (1990), 1968.
Another successful experiment with the conventional
planar magnetron has been made by W. Posadowski, Sur-
face and Coatings Technology 49 (1991) 290. In all
15   these cases, the experiments were successful only
with a cathode made of copper, and the selfsputtering
discharge on any other materials is not known.

        To distinguish between the selfsputtering dis-
charge and the conventional sputtering, the values of
20   discharge power and working pressure of the used wor-
king gas are important. At pressures higher than the
maximum selfsputtering pressure, practically unlimi-
ted reduction of the power fed into the discharge is
possible, without spontaneous extinction of the dis-
25   charge, compare Fig. 9. The discharge is thus excited
in a gas with a high enough pressure and the sputte-
ring is conventional. In the case of lower pressure
values than the maximum selfsputtering pressure, the-
re is always a minimum selfsputtering power, necessa-
30   ry for stable discharge excitation, where the minimum
selfsputtering power corresponds to the working pres-
sure. When the power fed into the discharge is redu-
ced to a value lower than the minimum selfsputtering
power, the discharge extinguishes. The minimum selfs-
35   puttering power increases when the working pressure

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is decreased. When the power fed into the discharge
is high enough, the working pressure can be reduced
without any limit, compare Fig. 9. The region of wor-
king pressures lower than the maximum selfsputtering
5   pressure and powers lower than the minimum selfsput-
tering power is thus a region of a stable selfsputte-
ring discharge excitation. For example in the paper
by W. Posadowski, Surface and Coatings Technology 49
(1991) 290, this region corresponded to the pressures
10 below the maximum selfsputtering pressure - about
$7*10^{-2}$ Pa in argon - and to the power density values
at a copper cathode over 37 W/cm² at this pressure
and over 67 W/cm² at the ultimate pressure of the va-
cuum device.

15

Disclosure of Invention

        The drawbacks of the prior art and reaching as
low working pressure as possible are solved by a me-
thod of magnetron sputtering according to the invent-
20 ion. The cathode to be sputtered is polarized with an
a.c. radio-frequency or a d.c. negative voltage with
respect to an anode and/or to a vacuum chamber, over
the cathode is formed a magnetic field, comprising
a closed tunnel of field lines above the cathode,
25 then a stable glow discharge is excited between the
cathode and the anode and/or the vacuum chamber at
a pressure greater than or equal to an ignition pres-
sure and then the working pressure of the working gas
is adjusted to a value greater than an extinction
30 pressure. The essence of the invention consists in
that a volume over the sputtered cathode surface is
affected by a magnetic field, the shape of which cor-
responds to the cathode shape. The field lines of the
said magnetic field, which intersect the cathode sur-
35 face twice, are spread on as large cathode area as

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possible, in particular on an area greater than 80%
of the total cathode surface area. The magnetic field
lines, which intersect the cathode surface twice, are
those, which emanate from the cathode closer to its
5   center and intersect the cathode back farther from
the center, or vice versa.

       For some applications it is essential to ignite
the discharge at as low pressure as possible. The
ignition pressure can be adjusted for example in the
10   range $3*10^{-2}$ Pa to 10^{-1} Pa, while the upper limit can
be even higher and the lower limit depends for exam-
ple on the size of the cathode and on the kind of the
gas. In this range it is possible to minimize the
ignition pressure with help of the voltage connected
15   to the cathode. Its value can be e.g. higher than
200 V, while the minimum ignition pressure is usually
reached in the range 500 V to 900 V.

       For some other applications the goal is to
reach stable sputtering at as low working pressure as
20   possible after the discharge is ignited. The extinc-
tion pressure can be adjusted for example in the ran-
ge $1.5*10^{-2}$ Pa to $5*10^{-2}$ Pa, while the upper limit
can be even higher and the lower limit again depends
for example on the size of the cathode and on the
25   kind of the gas.

       When the form of the magnetic field over the
cathode is retained, it is still possible to adjust
the magnetic field induction at the cathode surface.
Thus it is possible first of all to adjust the mini-
30   mum extinction pressure but also the ignition pressu-
re and the discharge voltage and/or the discharge
current. The induction in the middle of the field li-
nes tunnel has then a value higher than 50 G, nevert-
heless the minimum extinction pressure is usually re-
35   ached in the range 250 G to 1000 G.

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The minimum extinction pressure can be also ad-
justed with help of the discharge current. Normally,
the minimum extinction pressure is reached at lower
values of the discharge current, except for very low
5   current values, the optimum current density at the
cathode being usually in the range 0.2 to 20 mA/cm^2.

The magnetic field over the sputtered cathode
can be produced as a composition of at least two mag-
netic fields, namely of a magnetic field of magnetron
10   type and of a disbalancing magnetic field. The dis-
charge characteristics of the magnetron discharge are
then adjusted by means of the shape and intensity of
the resulting magnetic field, with help of varying
the intensity of at least one of the two magnetic
15   fields.

Another variant of method according to the in-
vention consists in the ignition process of the self-
sputtering discharge, involving three successive
stages: In the first stage, a low pressure magnetron
20   discharge is ignited between the cathode and the
anode and/or the vacuum chamber with the magnetic
field according to the basic method. In this stage,
the pressure of the ignition gas can be adjusted in
the interval $3*10^{-2}$ Pa to 100 Pa, and the negative
25   d.c. voltage at the cathode with respect to an anode
and/or to a vacuum chamber can be in the interval
300 V to 10 kV. Then, in the second stage, the power
of the discharge is increased to a value at least
equal to or higher than the value corresponding to
30   the power load of the sputtered cathode, related to
its entire area, in the range 2 to 250 W/cm^2, and, at
the same time, to a value at least equal to or higher
than the minimum selfsputtering power corresponding
to the cathode material. Finally, in the third stage
35   the working pressure of the chosen working gas is ad-

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justed to a value lower than the maximum selfsputte-
ring pressure and the discharge power is held on
a value corresponding to or higher than the minimum
selfsputtering power at the particular working pres-
5   sure. The cathode material is thus sputtered in
a stable selfsputtering discharge, excited in the at-
mosphere of the sputtered atoms or in the mixture of
the sputtered atoms with the working gas. In this
method, first during the second stage and not later
10   than during the third stage, the volume over the
sputtered cathode surface is affected by a magnetic
field with unbalanced magnetron shape. Thus, in the
third stage, all the parameters for the selfsputte-
ring discharge excitation are adjusted.

15   In summary, this method utilizes extremely good
plasma confinement by the magnetic field and thus it
makes possible to introduce highest possible power
into the discharge and to obtain high rate sputtering
and selfsputtering.

20   The working pressure values in the third stage
can be less than $1.5*10^{-2}$ Pa, that is lower than the
pressure values utilized so far in the unbalanced
magnetrons, and also less than the maximum selfsput-
tering pressure. The working gas can be the residual
25   gas and the working pressure is then the residual gas
pressure. The working gas can also be an inert gas,
for example neon, argon, krypton or xenon, or a reac-
tive gas, for example oxygen, nitrogen, carbon mono-
xide, carbohydrates and the like, or a mixture of
30   such gases.

            Another variant of the method according to the
invention consist in that, first during the second
stage and not later than during the third stage is
adjusted the chosen intensity of the magnetic field
35   of the magnetron type, used for selfsputtering, and

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the intensity of the disbalancing magnetic field,
used for selfsputtering, and the ratio of the inten-
sity of the magnetic field of the magnetron type to
the intensity of the disbalancing magnetic field,
5   used for selfsputtering, is equal to or less than
this ratio, used in the first ignition stage.

So, the most advantageous method of ignition of
the selfsputtering discharge is to ignite it under
the condititions optimized for the lowest ignition
10 pressure and then, in the third stage of selfsputte-
ring, the optimum magnetic field is either the same
or more unbalanced.

A simple method is keeping both the intensity
of the magnetic field of the magnetron type and the
15 intensity of the disbalancing magnetic field, used
for selfsputtering, identical to the intensities of
these fields, used in the first ignition stage.

Another variant uses reduction of the intensity
of the magnetic field of the magnetron type, used for
20 selfsputtering, as compared to the intensity of the
magnetic field of the magnetron type, used in the
first ignition stage, while the intensity of the dis-
balancing magnetic field, used for selfsputtering, is
identical with the intensity of the disbalancing mag-
25 netic field, used in the first ignition stage. Thus,
it is possible to achieve adjustment of the minimum
selfsputtering power and/or reduction of the minimum
discharge current and/or increase of the discharge
voltage, as compared to the values, achieved at the
30 selfsputtering using the former method.

The method of sputtering according to the in-
vention enables selfsputtering of many various mate-
rials. The material to be sputtered can be an element
belonging to the group copper, silver, gold, or an
35 alloy of at least two such elements. It can be also

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a low melting point material of the group lead, cad-
mium, or an alloy of such elements.

Selfsputtering is also possible for copper
alloys, such as various sorts of brass, that is alloy
5   of copper with zinc and/or with led, where the zinc
content is up to 50 weight percent and the led con-
tent is up to 10 weight percent.

The method also enables selfsputtering of some
bronzes, especially aluminium, manganese and nickel
10 based bronzes. In particular, these are alloys of
copper with aluminium, nickel, manganese and iron,
where the aluminium content is up to 11 weight per-
cent, the sum of the aluminium and manganese contents
is up to 16 weight percent, the nickel content is up
15 to 5 weight percent, and the iron content is up to
2 weight percent. This material can thus be for exam-
ple aluminium bronze, isabelin or novoconstantan.

The device for magnetron sputtering consists of
a vacuum chamber equipped with a gas inlet and a gas
20 outlet, of at least one planar cathode, the surface
of which is made of a material to be sputtered, pla-
ced in the vacuum chamber, of a supply of an a.c.
radio-frequency or a d.c. negative voltage, connected
between the cathode and the vacuum chamber and/or
25 between the cathode and a special anode, insulated
from the vacuum chamber and placed in the vacuum
chamber, and further of a cathode cooling circuit.
The device is also equipped with a supply of a magne-
tic field, comprising a closed tunnel of field lines
30 above the cathode. The essence of the invention con-
sists in the definition of the spatial distribution
of the magnetic field related to the shape and dimen-
sions of the sputtered cathode. The sputtered cathode
surface consists of an effective cathode area, limi-
35 ted by the field lines, which intersect the cathode

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surface twice, of a central cathode area, situated
inside and limited by the effective cathode area, and
of the marginal cathode area, situated outside and
limited by the effective cathode area. The effective
5   cathode area according to the invention is as large
as possible and it occupies at least 80% of the total
sputtered cathode surface. At the same time, the central
tral cathode area, or the marginal cathode area, or
even both, can be zero.

10   A variant of the device describes a flexible
layout, making possible to adjust the areas of the
effective, central and marginal cathode areas in an
optimal way for both low-pressure sputtering and
selfsputtering. The essence of this variant is that
15   the resulting magnetic field consists of the magnetic
fields of at least two independent magnetic field
supplies, namely of a supply of the magnetic field of
the magnetron type, placed behind the cathode
coaxially with the normal to the cathode surface at
20   its center, and of a supply of the disbalancing mag-
netic field, placed behind the cathode coaxially with
the normal to the cathode surface at its center, whi-
le at least one of both supplies is an electromagnet.
        The next variants of the device utilize
25   a simple magnetic circuit, placed for example behind
the cathode and composed for example of permanent
magnets or of one electromagnet.

        The cathode can have a circular or nearly cir-
cular shape and then the central cathode area should
30   occupy maximum 2% of the total sputtered cathode sur-
face and the marginal cathode area maximum 20% of the
total sputtered cathode surface, whereas the sum of
both is not greater than 20%.

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The cathode can also have an oblong shape, for
example a rectangular or an oval shape, and then the
central cathode area should occupy maximum 10% of the
total sputtered cathode surface and the marginal cat-
5   hode area maximum 15% of the total sputtered cathode
surface, whereas the sum of both is not greater than
20%.

The above-mentioned relative limits of the
areas are not sharp, and thus a weak effect, e.g.
10   decrease of the extinction pressure, is reached even
when these limits are exceeded slightly and, on the
contrary, for reaching greatest effects the practical
requirements must be even more strict.

Such strict requirements can be met in a device
15   according to another variant, where the shape of the
cathode is defined by the shape of the curve, which
demarcates the effective area of the cathode. If for
example the magnetic field exhibits axial symmetry,
then the cathode has a circular shape. In the case of
20   a magnetic field produced by a rectangular magnetic
circuit, the cathode in general will not have rectan-
gular shape, but a shape defined with the shape and
dimensions of the effective cathode area, for example
an oblong shape with rounded corners.

25   According to another variant of the device the
cathode might have a rectangular shape but the margin
of the cathode is covered with a shielding cover made
of a conducting, non-magnetic material, which is
electrically insulated from the cathode and the inner
30   dimensions of which correspond to the dimensions of
the effective area of the cathode. The shielding co-
ver can be electrically connected to the anode or to
the vacuum chamber or it can be kept on a selected
potential, including the floating potential in the
35   plasma. The discharge then is not excited in the spa-

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ce between the shielding cover and the margin of the
cathode and it is confined to the effective cathode
area.

       In the case when a basis of the magnetic field
5   supply is identical with the magnetic field supply of
a conventional magnetron, where the central cathode
area occupies more than 10% of the total sputtered
cathode area, a frame made of a magnetic soft
material is placed above the outer edge of the catho-
10   de, electrically connected to the cathode, which att-
racts the field lines emanating from the cathode cen-
ter and thus widens the effective cathode area.

       In case of the device with two electromagnets,
the supply of the magnetic field of the magnetron ty-
15   pe can be a first coil, placed behind the cathode co-
axially with the normal to the cathode surface at its
center, connected to a first current supply, and in-
side the first coil a first core of a magnetic soft
material can be placed. The supply of the disbalan-
20   cing magnetic field can be a second coil with dimen-
sions approximately equal to or greater than the cat-
hode dimensions, placed behind the cathode coaxially
with the normal to the cathode surface at its center,
connected to a second current supply. Behind the cat-
25   hode, around the first coil, a second core can be
placed, with a ring shape, made of a magnetically
conducting material. The second coil can be placed on
the second core and the first core together with the
second core can be magnetically connected behind the
30   first coil with help of a plate made of a magnetical-
ly conducting material.

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Brief Description of Drawings

The invention is described in more detail in 13 drawings.

Fig. 1 shows a schematic design of one possible embodiment of the device for magnetron sputtering according to the invention.

Fig. 2 shows a graph presenting the ignition pressure and the extinction pressure as functions of the ratio of currents I_2/I_1 in the device shown in Fig. 1.

Figs. 3, 4, and 5 show the shapes of field lines in one half of a cross-section in a circular magnetron, in a plane which contains the magnetron axis, and the figures correspond, respectively, to the points A, B, and C in Fig. 2 and to the values of the ratio I_2/I_1: 1.25, 2.13, and 5.00.

Figs. 6.1 and 6.2 show, for a comparison, a cathode and the shape of the magnetic field of a magnetron according to the prior art, and also a design according to the invention, with a frame made of a soft magnetic material.

Fig. 7 shows a detail of the cathode, the shape of which is defined with the shape of the effective area.

Fig. 8 shows a detail of a cathode with a shielding cover.

Fig. 9 shows areas of stable excitation of the magnetron discharge as a function of the discharge power, including the distinction of the conventional sputtering and selfsputtering.

Figs. 10 and 11 show the characteristics of the selfsputtering discharge in the magnetron with a brass cathode. Fig. 10 shows minimum discharge current as a function of the intensity of the magnetic field of the magnetron type. Fig. 11, shows the mini-

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mum power density as a function of the intensity of
the disbalancing magnetic field.

Fig. 12 shows minimum argon pressure and dis-
charge voltage as a function of the discharge current
5   in a magnetron with cathode made of pure lead.

Detailed Description of the Invention - Examples of arrangement

10   Example 1

Fig. 1 shows a vacuum chamber $\underline{1}$ equipped with
a gas inlet $\underline{2}$ and a gas outlet $\underline{3}$, in which an insula-
ted planar circular cathode $\underline{4}$ is placed. A supply $\underline{5}$
of a d.c. negative voltage and current is connected
15   between the cathode $\underline{4}$ and the vacuum chamber $\underline{1}$. The
cooling circuit $\underline{6}$ enables flow of a cooling liquid.
A magnetic field supply, comprising two electromag-
nets, is placed behind the cathode $\underline{4}$. The supply of
the magnetic field of the magnetron type is a first
20   coil $\underline{7}$, connected to a first current supply $\underline{8}$, and
inside the first coil $\underline{7}$ is placed a first core $\underline{9}$ of
a magnetic material. The supply of the disbalancing
magnetic field is a second coil $\underline{11}$ with dimensions
approximately equal to the cathode dimensions, con-
25   nected to a second current supply $\underline{12}$. Behind the cat-
hode $\underline{4}$, around the first coil $\underline{7}$ but inside the second
coil $\underline{11}$, a second core $\underline{13}$ is placed, with a ring sha-
pe, made of a magnetically soft material. The first
core $\underline{9}$ together with the second core $\underline{13}$ are magneti-
30   cally connected behind the first coil $\underline{7}$ with help of
a plate $\underline{14}$ made of a magnetically conducting mate-
rial. In this example the relationship of the cathode
$\underline{4}$ dimensions and the magnetic field shape is such that
the effective cathode area $\underline{15}$, defined by the field
35   lines $\underline{301},\underline{302}$ comprises almost entire cathode sur§

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face, the central cathode area 16 occupies only about
0.05% of the total sputtered cathode 4 surface and
the marginal cathode area is missing. The field line
302 delimits the effective cathode area 15. The cent-
5   ral cathode area 16, the marginal cathode area, and
the effective cathode area 15 can be adjusted with
help of the ratio of currents I_2/I_1, where I_1 is the
current from the first current supply 8 to the first
coil 7 and I_2 is the current from the second current
10 supply 12 to the second coil 11.

Example 2

Fig. 2 shows a graph of the ignition pressure
and of the extinction pressure as functions of the
15 ratio of the intensity of the disbalancing magnetic
field to the intensity of the magnetic field of the
magnetron type in the device shown in Fig. 1 with
a circular cathode with diameter 124 mm, made of
brass. Its approximate composition was 58 weight per-
20 cent of copper, 40 weight percent of zinc and 2
weight percent of lead. The working gas was argon.
The discharge current was 1 A and the ignition volta-
ge was 1000 V. The ratio of currents I_2/I_1 is a mea-
sure of the ratio of both magnetic fields, where I_1
25 is the current from the first current supply 8 to the
first coil 7 and I_2 is the current from the second
current supply 12 to the second coil 11. The curve
201 shows the ignition pressure and the curve 202 the
extinction pressure as functions of the ratio I_2/I_1.
30 Both curves 201 and 202 exhibit a pronounced minimum,
labelled B, corresponding to the ratio $I_2/I_1=2.13$.
This ratio corresponds to the magnetic field shape,
given in Fig. 4. The point A corresponds to the ratio
$I_2/I_1=1.25$ and to the magnetic field shape given in
35 Fig. 3, and the point C corresponds to the ratio

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$I_2/I_1=5.0$ and to the magnetic field shape, given in
Fig. 5. Figs. 3, 4, and 5 show the shapes of field
lines in one half of a cross-section in the circular
magnetron in a plane which contains the magnetron
5   axis. The field lines 301 intersect the cathode sur-
face 4 twice and the field line 302 is the most dis-
tant of such field lines. The intersections of the
field lines 302 with the cathode surface 4 thus deli-
mit the effective cathode area 15. The field lines
10   303 in Fig. 3 emanate from the central cathode area
16 and do not intersect the cathode 4 twice but they
intersect for example the vacuum chamber 1 outside
the cathode 4. Analogously, the field lines 304 in
Fig. 5 emanate from the marginal cathode area 17 and
15   do not intersect the cathode 4 twice. In Fig. 4, the
central cathode area 16 and the marginal cathode area
17 almost do not exist and the field lines 302 just
connect the central point of the cathode 4 with its
edge. The effective cathode area 15 thus occupies
20   practically the entire sputtered cathode surface 4
and, just in this arrangement, one reaches the best
plasma confinement at the magnetron cathode 4 as well
as the minimum ignition and extinction pressures.

25   Example 3

          Identical conclusions about the
inter-relationship between the magnetic field shape
above the cathode and the minimum ignition and extin-
ction pressures, like in Example 2, were gained in
30   a magnetron with a circular cathode with diameter
100 mm made of copper, and also with another cathode
made of titanium.

Example 4

In the same arrangement as in Example 1, at the
ratio $I_2/I_1 = 2.13$, the ignition pressures were measu-
red as a function of the voltage led to the cathode
5   to ignite the discharge, in the range 400 V to
1000 V. The ignition pressures was in the range
$3*10^{-2}$ Pa to $8*10^{-2}$ Pa, while the minimum was found
in the range 700 V to 750 V.

10 Example 5

In the same arrangement as in Example 1, at the
ratio $I_2/I_1 = 2.0$ and at the discharge current 175 mA,
the extinction pressures were measured as a function
of the magnetic field induction at the cathode surfa-
15 ce in the center of the field line tunnel in the ran-
ge of values between 160 G and 600 G . The extinction
pressure was in the range $1.5*10^{-2}$ Pa to
$2.3*10^{-2}$ Pa, while the minimum was found at the mag-
netic field induction of approximately 400 G. Compa-
20 rison of this example with example 2 shows that the
magnetic field shape and the effective cathode area
exhibit more pronounced effect on the extinction
pressure values than the magnetic field induction.

25 Example 6

In the same arrangement as in Example 1, at the
ratio $I_2/I_1 = 2.13$, the extinction pressures were mea-
sured as a function of the discharge current in the
range 50 mA to 3 A. The extinction pressure was in
30 the range $1.5*10^{-2}$ Pa to $3*10^{-2}$ Pa, while the minimum
was found at the discharge current about 175 mA. This
corresponds to a discharge current density about
1.5 mA/cm^2 .

Example 7

        Another example of the device according to the
invention is shown in Figs. 6.1 and 6.2.
        Fig. 6.1 shows schematically, in a cross-section, the
5   cathode 4 and the magnetic circuit 602 of a conven-
tional magnetron according to the prior art.
        Fig. 6.2 shows an example of the device according to
the invention, where, compared to Fig. 6.1, a frame
601 made of a soft magnetic material is added above
10 the outer edge of the cathode 4 and the frame is
electrically connected to the cathode 4. The frame
601 attracts very effectively the magnetic field li-
nes, thus widening the effective cathode area 15 and
making better magnetic field confinement above the
15 sputtered cathode 4. This design results in a signi-
ficant reduction of the extinction pressure.

        It has been found experimentally that while the
conventional magnetron with a Ti cathode with dia-
meter 100 mm exhibits minimum extinction pressure
20 8.2×10^{-2} Pa at the discharge current 0.5 A, the ex-
tinction pressure of the same magnetron, with the
frame 601 added, is reduced down to only
4.3×10^{-2} Pa, i.e. to about one half. Another advanta-
ge is that the coil current necessary for the extin-
25 ction pressure minimum dropped from 1.4 A down to
0.9 A in case of using the Fe frame 601.

        Example 8

        Fig. 7 shows an example of the design, where
30 the magnetic field is produced by a rectangular mag-
netic circuit 701. The field lines 302 demarcate the
edges of the effective cathode area 15. The shape of
the cathode 4 is defined by the outer edge of the ef-
fective cathode area 15, it has thus an oblong shape
35 with rounded corners. Therefore the marginal cathode

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area is eliminated and only a small central cathode
area 16 remains.

Example 9

5   Fig. 8 shows, in a cross-section, the cathode
4 with the magnetic circuit 801. The margin of the
cathode 4 is covered with a shielding cover 802, the
inner dimensions of which are defined by the outer
edge of the effective cathode area 15. The shielding
10   cover 802 is made of a conducting, non-magnetic mate-
rial and it is electrically insulated from the catho-
de 4. The shielding cover 802 is mechanically fixed
to the vacuum chamber 1 via the insulation 803. So,
it is kept on the floating potential. It also can
15   form the discharge anode or be electrically connected
to the vacuum chamber. The discharge then is not ex-
cited in the space between the shielding cover 802
and the margin of the cathode 4 and it is confined to
the effective cathode area 15. Therefore, in this de-
20   sign, it is not important how large is the marginal
cathode area, covered with the shielding cover 802.

Example 10

Figs. 10 and 11 show the characteristics of the
25   selfsputtering discharge in a magnetron, described in
Fig.1 and in example 1, having circular cathode with
diameter 124 mm, made of brass. In this case, the
working gas in the third stage was the residual gas
and the working pressure was the residual gas pressu-
30   re of about $2*10^{-3}$ Pa. Fig.10 shows, how the minimum
discharge current depends on the current I_1, that is
on the intensity of the magnetic field of the magnet-
ron type. The current I_2 is here a parameter of the
curves. The points, marked by small circles, label
35   the ratio $I_2/I_1=2.13$, when minimum ignition pressure

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is achieved in the first stage of discharge ignition.
Fig.10 illustrates how it is possible to reduce the
minimum discharge with help of reduction of the in-
tensity of the magnetic field of the magnetron type
5   by the reduction of the current I_1. It is also evi-
dent that provided the ratio of currents I_2/I_1 is
·kept higher than 2.13, then the magnetron discharge
current is adjusted especially with help of the in-
tensity of the magnetic field of the magnetron type,
10   or of the current I_1. In contrast, provided the ratio
of currents I_2/I_1 is less than 2.13, then the minimum
discharge current begins to increase sharply.

       Fig.11 shows, how the minimum power density
can be adjusted with help of adjustment of the cur-
15   rent I_2, or of the intensity of the disbalancing mag-
netic field. The current I_1 is here a parameter of
the curves. The points, marked by small circles, la-
bel again the ratio $I_2/I_1=2.13$. Fig. 11 again illust-
rates that provided the ratio of currents I_2/I_1 is
20   kept higher than 2.13, then the minimum power density
in selfsputtering is approximately constant. These
values are lower for each curve with a constant value
I_1 than if the current I_2 gets lower than approxima-
tely 2.13 * I_1.

25   Optimum regime of selfsputtering discharge ig-
nition has been achieved for example using the follo-
wing procedure: The magnetron discharge was ignited
in argon at a pressure $4*10^{-2}$ Pa and at the currents
$I_1 = 2$ A, $I_2 = 4$ A, that is at $I_2/I_1 = 2$. Thus, in
30   the first stage of discharge ignition, the ratio of
the intensity of the magnetic field of the magnetron
type to the intensity of the disbalancing magnetic
field was used, at which the field lines of the re-
sulting magnetic field occupy an area greater than
35   80% of the total cathode surface area. In the second

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stage, at an argon pressure $4*10^{-2}$ Pa, the power of
the glow discharge was increased from the value
0.1 kW up to 4.4 kW, then the current I_1 was reduced
for example down to 1 A, that is to $I_2/I_1 = 4$. Thus,
5   in this case, the ratio of the intensity of the mag-
netic field of the magnetron type to the intensity of
the disbalancing magnetic field, used for selfsputte-
ring, is less than this ratio, used in the first ig-
nition stage. In the third stage, the working
10   pressure of the working gas was adjusted to the resi-
dual pressure of $2 * 10^{-3}$ Pa and at these conditions,
a stable sustained selfsputtering discharge was ope-
rated at power values of 4.1 kW and higher. This is
lower value than what would be achieved provided
15   identical magnetic field were kept as in the first
stage of discharge ignition.

Example 11

In a circular planar magnetron having cathode
20   with diameter 124 mm, made of pure copper, qualitati-
vely very similar results as in example 10 were achi-
eved, especially in dependence on the intensity of
the magnetic field of the magnetron type and on the
intensity of the disbalancing magnetic field. Selfs-
25   puttering in the residual gas atmosphere at pressure
$2*10^{-3}$ Pa was achieved at minimum discharge current
values down to 9.8 A and at discharge voltage values
from 585 V to 750 V. At the current $I_1 = 1.0$ A and
$I_2 = 4$ A, a stable selfsputtering discharge with
30   a copper cathode was achieved at minimum power densi-
ty of only 56.7 W/cm^2. This is significantly lower
value than the lowest power density published so far
with a conventional magnetron, namely 67 W/cm^2.

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Example 12

When a similar circular planar magnetron as in
example 1 was used, but with a cathode with diameter
100 mm, made of pure silver, selfsputtering in the
5   residual gas atmosphere at pressure $2*10^{-3}$ Pa was
achieved at minimum discharge current about 3 A and
at discharge voltage about 760 V, that is at power
density about 29 W/cm^2.

10 Example 13

In a circular planar magnetron as in example
12, having a cathode with diameter 100 mm, made of
pure lead, the extinction argon pressure and dischar-
ge voltage were measured as functions of the minimum
15 discharge current, and the results achieved are shown
in Fig. 12. A stable selfsputtering discharge was ob-
served in a mixture of the sputtered lead atoms with
argon gas, at argon pressures lower than about
$2.3*10^{-2}$ Pa, and at minimum discharge current value
20 between 0.4 A and 0.75 A. This corresponds to achie-
vement of selfsputtering discharge at minimum power
density between 2.4 and 6.6 W/cm^2. When the magnetic
field was optimized, minimum power density 2.1 W/cm^2
was achieved with this cathode at argon pressure
25 $2.2*10^{-2}$ Pa and minimum power density 4.9 W/cm^2 at
pressure $2.3*10^{-3}$ Pa.

Example 14

In a similar experiment as in example 13 but
30 with a cathode made of pure cadmium, selfsputtering
discharge was achieved at argon pressure lower than
about $2*10^{-2}$ Pa and at minimum discharge current bet-
ween 0.8 and 1.5 A.

Example 15

Another measurement was made in a circular pla-
nar magnetron as in example 12, with a cathode with
diameter 100 mm, made of aluminium bronze with the
5   following composition: 9 weight percent of aluminium,
4 weight percent of nickel, 1.2 weight percent of
manganese and 1 weight percent of iron, where the
rest was copper. Stable selfsputtering discharge was
achieved, even in the residual gas atmosphere at
10   pressure about $2*10^{-3}$ Pa. The minimum power density
was 77 W/cm^2. The method according to the invention
thus enables even selfsputtering of alloys, contai-
ning an element which does not allow selfsputtering
in its pure form. The concentration of this element
15   must not exceed a particular limit, which depends on
the alloy components.

Industrial Applicability

20   The invention can be utilized especially for
the ignition and maintaining of a magnetron discharge
at low pressures, down to the values of about
$1.5*10^{-2}$ Pa and of a selfsputtering discharge at
pressures in the order of magnitude from $5*10^{-2}$ Pa
25   down to the residual pressure of the vacuum device.
Such magnetron discharges feature the advantage of
wider ranges of operation parameters compared to con-
ventional magnetron sputtering. When used for thin
film deposition, it reduces the film contamination by
30   the gas species, enables a wider ranges of deposited
film parameters, reduces the collision probability of
the sputtered atoms with the gas, thus reducing their
thermallization and enabling straight-line movement
of particles.

The advantage of the selfsputtering discharge
consists in high values of applied power and thus in
high sputtering rates. Moreover, a large fraction of
the sputtered atoms is ionized.

5   The method according to the invention is appl-
icable for the film deposition for the so-called
lift-off technology, covering of step-like structures
with a high ratio of the step height to the step
width, or hole filling for holes with a high
10   depth/diameter ratio and the like. It can for example
exclude or suppress contamination of the films by
gas, it minimizes the probability of collisions of
the sputtered atoms with the gas, thus eliminating
their thermallization and it enables straight-line
15   movement of particles. The application of the invent-
ion is, however, not necessarily restricted just to
the thin film deposition but it can be used for exam-
ple for low pressure etching.

20   (End of Description)

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CLAIMS

1) A method of magnetron sputtering, where the
cathode to be sputtered is polarized with an a.c.
radio-frequency or a d.c. negative voltage with res-
pect to an anode and/or to a vacuum chamber, over the
5   cathode is formed a magnetic field, comprising a clo-
sed tunnel of field lines above the cathode, then
a stable glow discharge is excited between the catho-
de and the anode and/or the vacuum chamber at a pres-
sure greater than or equal to an ignition pressure
10   and then the working pressure of the working gas is
adjusted to a value greater than an extinction pres-
sure, characterized in that a volume over the sputte-
red cathode surface is affected by a magnetic field
and the field lines of the said magnetic field, which
15   intersect the cathode surface twice, are spread on an
area greater than 80% of the total cathode surface
area.

2) A method in accordance with claim 1, cha-
20   racterized in that the ignition pressure has a value
greater than or equal to $3*10^{-2}$ Pa.

3) A method in accordance with claim 1, cha-
racterized in that the extinction pressure has a va-
25   lue greater than or equal to $1.5*10^{-2}$ Pa.

4) A method in accordance with claim 2, cha-
racterized in that the minimum ignition pressure is
adjusted with help of the voltage connected to the
30   cathode.

5) A method in accordance with claim 3, cha-
racterized in that the minimum extinction pressure is

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adjusted with help of the magnetic field induction at
the cathode surface.

6) A method in accordance with claim 3, cha-
5   racterized in that the minimum extinction pressure is
adjusted with help of the discharge current.

7) A method in accordance with claim 1, cha-
racterized in that the magnetic field over the sput-
10 tered cathode is produced by composition of at least
two magnetic fields, namely of a magnetic field of
magnetron type and of a disbalancing magnetic field,
while the discharge characteristics of the magnetron
discharge are adjusted by means of the shape and in-
15 tensity of the resulting magnetic field with help of
varying the intensity of at least one of the two mag-
netic fields.

8) A method in accordance with claim 1, cha-
20 racterized in that the ignition process of the self-
sputtering discharge consists of three successive
stages, where in the first stage a low pressure mag-
netron discharge is ignited between the cathode and
the anode and/or the vacuum chamber with the magnetic
25 field according to claim 1, in the second stage the
power of the discharge is increased to a value at
least equal to or higher than the value corresponding
to the power load of the sputtered cathode, related
to its entire area, in the range 2 to 250 W/cm^2, and
30 to a value at least equal to or higher than the mini-
mum selfsputtering power corresponding to the cathode
material, and in the third stage the working pressure
of the chosen working gas is adjusted to a value
lower than the maximum selfsputtering pressure and
35 the discharge power is held on a value corresponding

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to or higher than the minimum selfsputtering power at
the particular working pressure and the cathode mate-
rial is sputtered in a stable selfsputtering dischar-
ge, excited in the atmosphere of the sputtered atoms
5   or in the mixture of the sputtered atoms with the
working gas, while, first during the second stage and
not later than during the third stage, the volume
over the sputtered cathode surface is affected by
a magnetic field with unbalanced magnetron shape.
10

        9)   A method in accordance with claim 8, cha-
racterized in that the working pressure of the wor-
king gas in the third stage has a value lower than
$1.5*10^{-2}$ Pa.

15

        10)   A method in accordance with claim 7 and 8,
characterized in that first during the second stage
and not later than during the third stage is adjusted
the chosen intensity of the magnetic field of the
20   magnetron type, used for selfsputtering, and the in-
tensity of the disbalancing magnetic field, used for
selfsputtering, and the ratio of the intensity of the
magnetic field of the magnetron type to the intensity
of the disbalancing magnetic field used for selfsput-
25   tering is equal to or less than this ratio, used in
the first ignition stage.

        11)   A method in accordance with claim 10, cha-
racterized in that both the intensity of the magnetic
30   field of the magnetron type and the intensity of the
disbalancing magnetic field, used for selfsputtering,
are identical to the intensities of these fields,
used in the first ignition stage.

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12) A method in accordance with claim 10, cha-
racterized in that the adjustment of the minimum sel-
fsputtering power and/or reduction of the minimum
discharge current and/or increase of the discharge
5   voltage, as compared to the values achieved at the
selfsputtering in the method in accordance with claim
11, is achieved by means of a reduction of the inten-
sity of the magnetic field of the magnetron type,
used for selfsputtering, as compared to the intensity
10 of the magnetic field of the magnetron type, used in
the first ignition stage, while the intensity of the
disbalancing magnetic field, used for selfsputtering,
is identical with the intensity of the disbalancing
magnetic field, used in the first ignition stage.

15

13) A method in accordance with claim 8, cha-
racterized in that the material to be sputtered is an
element belonging to the group copper, silver, gold,
or an alloy of at least two such elements.

20

14) A method in accordance with claim 8, cha-
racterized in that the material to be sputtered is an
element belonging to the group lead, cadmium, or an
alloy of such elements.

25

15) A method in accordance with claim 8, cha-
racterized in that the material to be sputtered is an
alloy of copper with zinc and/or with lead, where the
zinc content is up to 50 weight percent and the lead
30 content is up to 10 weight percent.

16) A method in accordance with claim 8, cha-
racterized in that the material to be sputtered is an
alloy of copper with aluminium, nickel, manganese and
35 iron, where the aluminium content is up to 11 weight

percent, the sum of the aluminium and manganese con-
tents is up to 16 weight percent, the nickel content
is up to 5 weight percent, and the iron content is up
to 2 weight percent.

5

17) A device for magnetron sputtering to per-
form the method in accordance with claim 1 and 8,
consisting of a vacuum chamber equipped with a gas
inlet and a gas outlet, of at least one planar catho-
10 de, the surface of which is made of a material to be
sputtered, placed in the vacuum chamber and equipped
with a cooling circuit, of a supply of an a.c.
radio-frequency or a d.c. negative voltage, connected
between the cathode and the vacuum chamber and/or
15 between the cathode and a special anode, insulated
from the vacuum chamber and placed in the vacuum
chamber, and the device is further equipped with
a supply of a magnetic field, comprising a closed
tunnel of field lines above the cathode, characteri-
20 zed in that the sputtered cathode surface (4) con-
sists of an effective cathode area (15), limited by
the field lines (301,302), which intersect the catho-
de surface twice, of a central cathode area (16), si-
tuated inside and limited by the effective cathode
25 area (15), and of the marginal cathode area (17), si-
tuated outside and limited by the effective cathode
area (15), while the effective cathode area (15) oc-
cupies at least 80% of the total sputtered cathode
surface (4).

30

18) A device in accordance with claim 17 to
perform the method in accordance with claim 7, cha-
racterized in that the magnetic field supply consists
of at least two independent magnetic field supplies,
35 namely of a supply of the magnetic field of the mag-

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netron type, placed behind the cathode coaxially with
the normal to the cathode surface at its center, and
of a supply of the disbalancing magnetic field, pla-
ced behind the cathode coaxially with the normal to
5   the cathode surface at its center, while at least one
of both supplies is an electromagnet.

19)   A device in accordance with claim 17 cha-
racterized in that the cathode (4) has a circular
10   shape and that the central cathode area (16) occupies
maximum 2% of the total sputtered cathode surface
(4) and the marginal cathode area (17) occupies maxi-
mum 20% of the total sputtered cathode surface (4),
whereas the sum of both is not greater than 20%.
15

20)   A device in accordance with claim 17, cha-
racterized in that the cathode (4) has an oblong sha-
pe, for example a rectangular or an oval shape, and
that the central cathode area (16), occupies maximum
20   10% of the total sputtered cathode surface (4) and
the marginal cathode area (17) occupies maximum 15%
of the total sputtered cathode surface (4), whereas
the sum of both is not greater than 20%.

25   21)   A device in accordance with claim 17, cha-
racterized in that the shape of the cathode (4) is
defined by the shape of the curve, which demarcates
the effective area (15) of the cathode (4).

30   22)   A device in accordance with claim 17, cha-
racterized in that the margin of the cathode (4) is
covered with a shielding cover (802) made of a con-
ducting, non-magnetic material, which is electrically
insulated from the cathode (4) and the inner dimensi-

ons of which correspond to the dimensions of the ef-
fective area (15) of the cathode (4).

5   23)   A device in accordance with claim 17, cha-
racterized in that a frame (601) made of a magnetic
soft material is placed above the outer edge of the
cathode (4) and the frame is electrically connected
to the cathode (4).

10   24)   A device in accordance with claim 18, cha-
racterized in that the supply of the magnetic field
of the magnetron type is a first coil (7), placed be-
hind the cathode (4) coaxially with the normal to the
cathode (4) surface at its center, connected to
15   a first current supply (8), and inside the first coil
(7), a first core (9) of a magnetic material is pla-
ced, behind the cathode (4) around the first coil
(7) a second core (13) is placed, with a ring shape
and made of a magnetically conducting material, the
20   supply of the disbalancing magnetic field is a second
coil (11) with dimensions approximately equal to or
greater than the cathode (4) dimensions, placed be-
hind the cathode coaxially with the normal to the
cathode (4) surface at its center, connected to a se-
25   cond current supply (12), placed on the second core
(13), and the first core (9) together with the second
core (13) are magnetically connected behind the first
coil (7) with help of a plate (14) made of a magneti-
cally conducting material.

30

(End of Claims)

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FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5
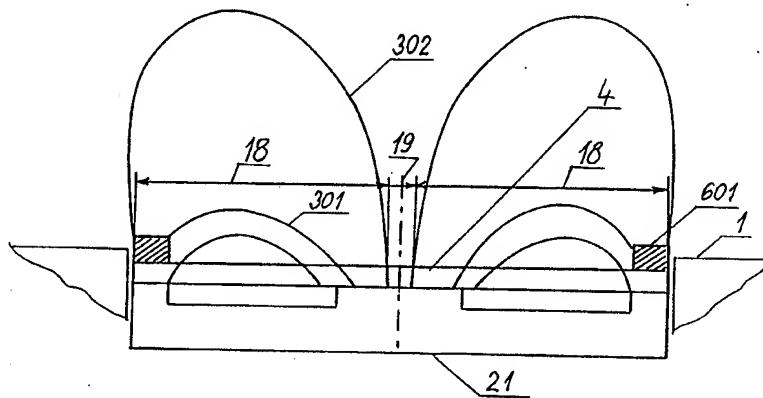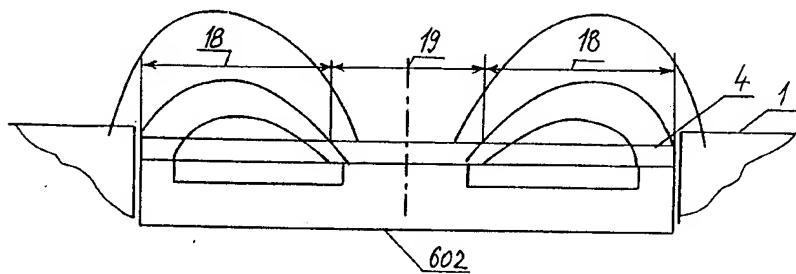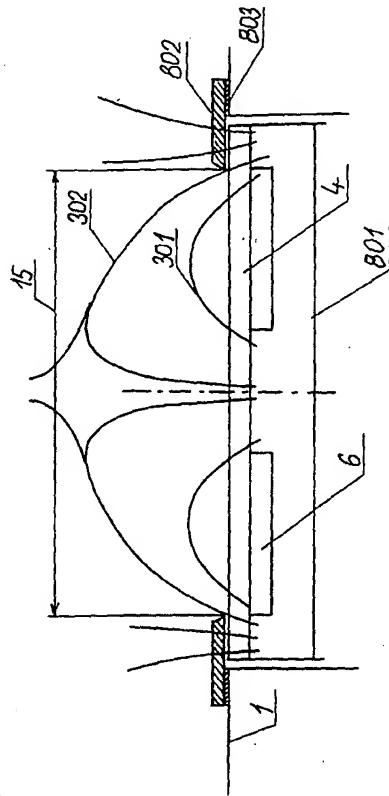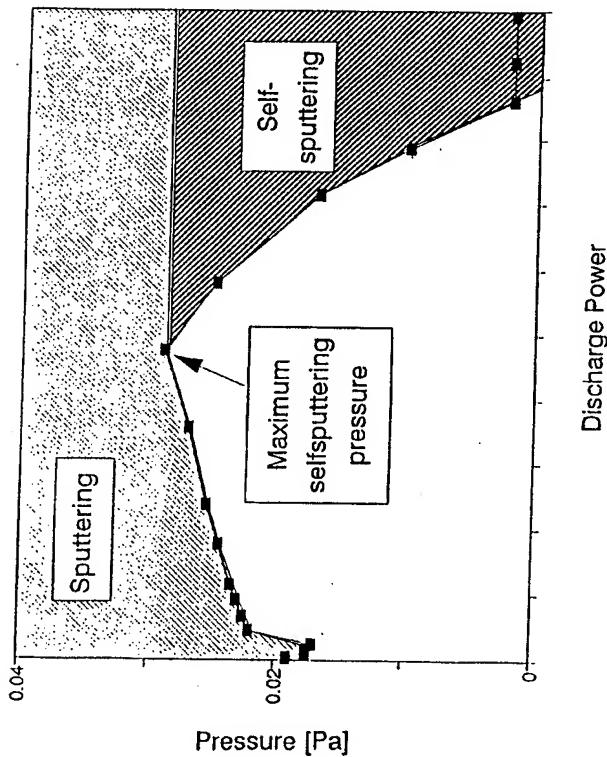
FIG. 6.1

FIG. 6.2
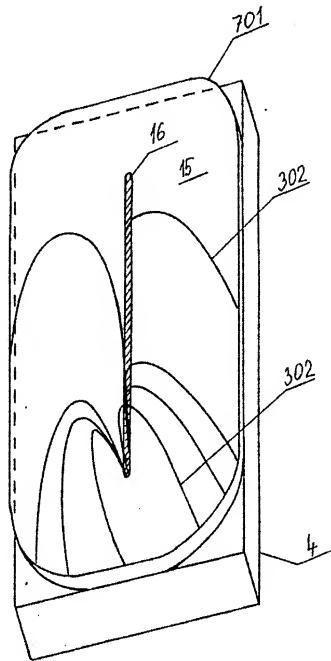
FIG. 7

FIG.8

FIG. 9

FIG. 10
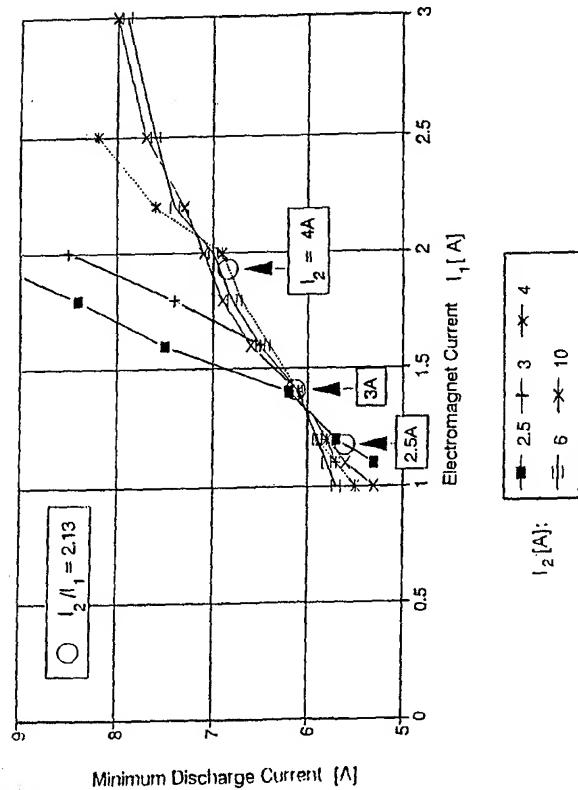
FIG. 11
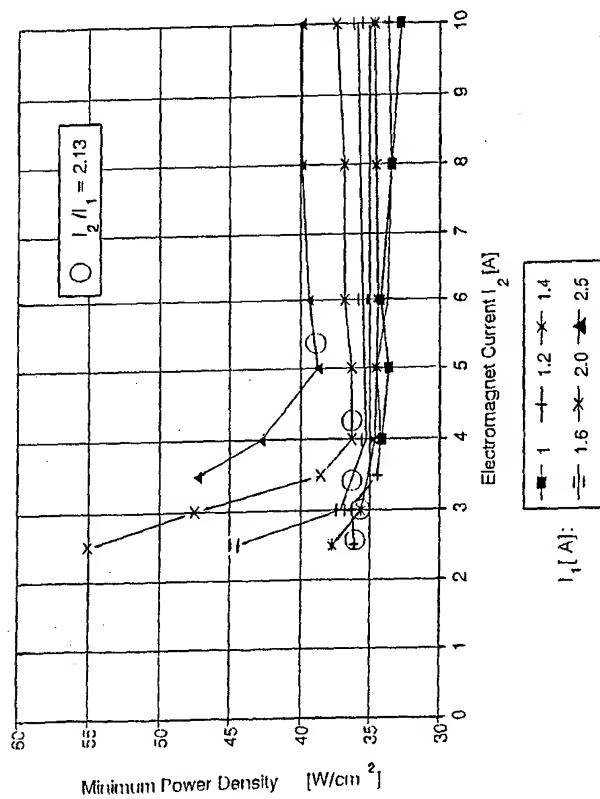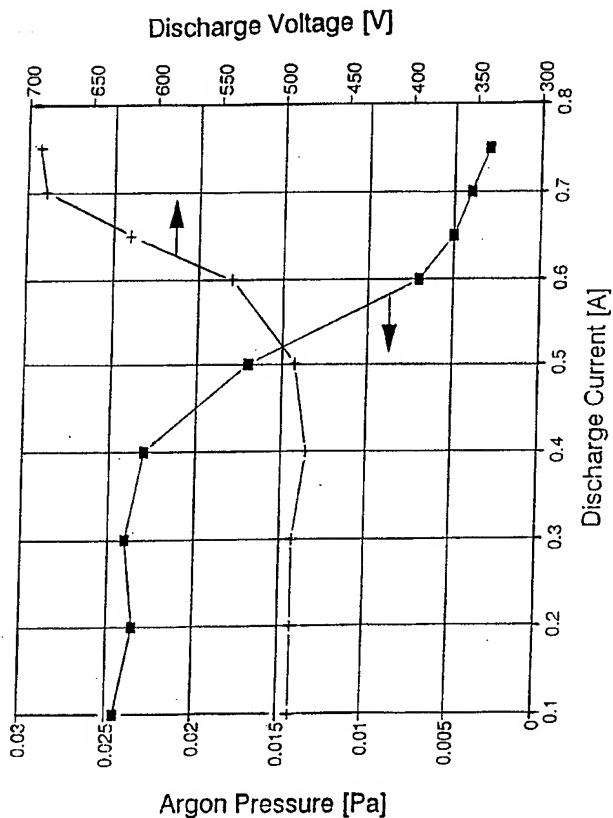
FIG. 12

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H01J37/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 865 708 (WELTY) 12 September 1989 see column 9, line 52 - line 68; figures 1,9 ---	1,7, 17-20,24
A	JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART A., vol.10, no.6, November/December 1992, NEW YORK US pages 3430 - 3433 T. ASAMAKI ET AL. 'High-vacuum planar magnetron discharge.' see the whole document ---	1-4,6, 17-19
A	GB,A,2 255 105 (ION COAT LIMITED) 28 October 1992 see page 7, paragraph 2 - page 8, paragraph 1; figure 1 ---	1,17, 22-24

-/--

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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Date of the actual completion of the international search	Date of mailing of the international search report
28 November 1994	30. 11. 94

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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